Figure 2-43.—Tornadic Vortex Signature (TVS) product.

independently and determines whether the product will forecast an entire hour's movement, a 45-, 30-, or 15-minute movement, or simply omit a forecast for any given storm. Up to 100 storms may be monitored simultaneously.

If a storm's motion exceeds certain thresholds, the STI algorithm may become confused. It bases forecasts on linear extrapolation of past movement. Therefore, storms traveling in a curved path or changing direction will not be accurately forecast. STI is intended for well-defined, isolated thunderstorms. Under any other circumstance (i.e., squall lines, LEWPs, etc.) the algorithm becomes confused, resulting in a questionable product. If storms have crossing paths, or are in close proximity to one another,

the algorithm might misidentify them and in extreme cases, identify them as a single storm.

Hail Index (HI) Product

The Hail Index (HI) product scans all storms within the radar coverage area and searches for very high reflectivity values located above the freezing level. It then provides an indication of which storms are expected to produce hail. All storms are examined for hail potential, then categorized accordingly. While the algorithm is not foolproof, it provides a valuable first guess. The hail product provides estimates on the probability of hail, probability of severe hail, and maximum expected hail size. The hail product provides an extremely simple display, making it a good overlay for other products. As you can see in figure
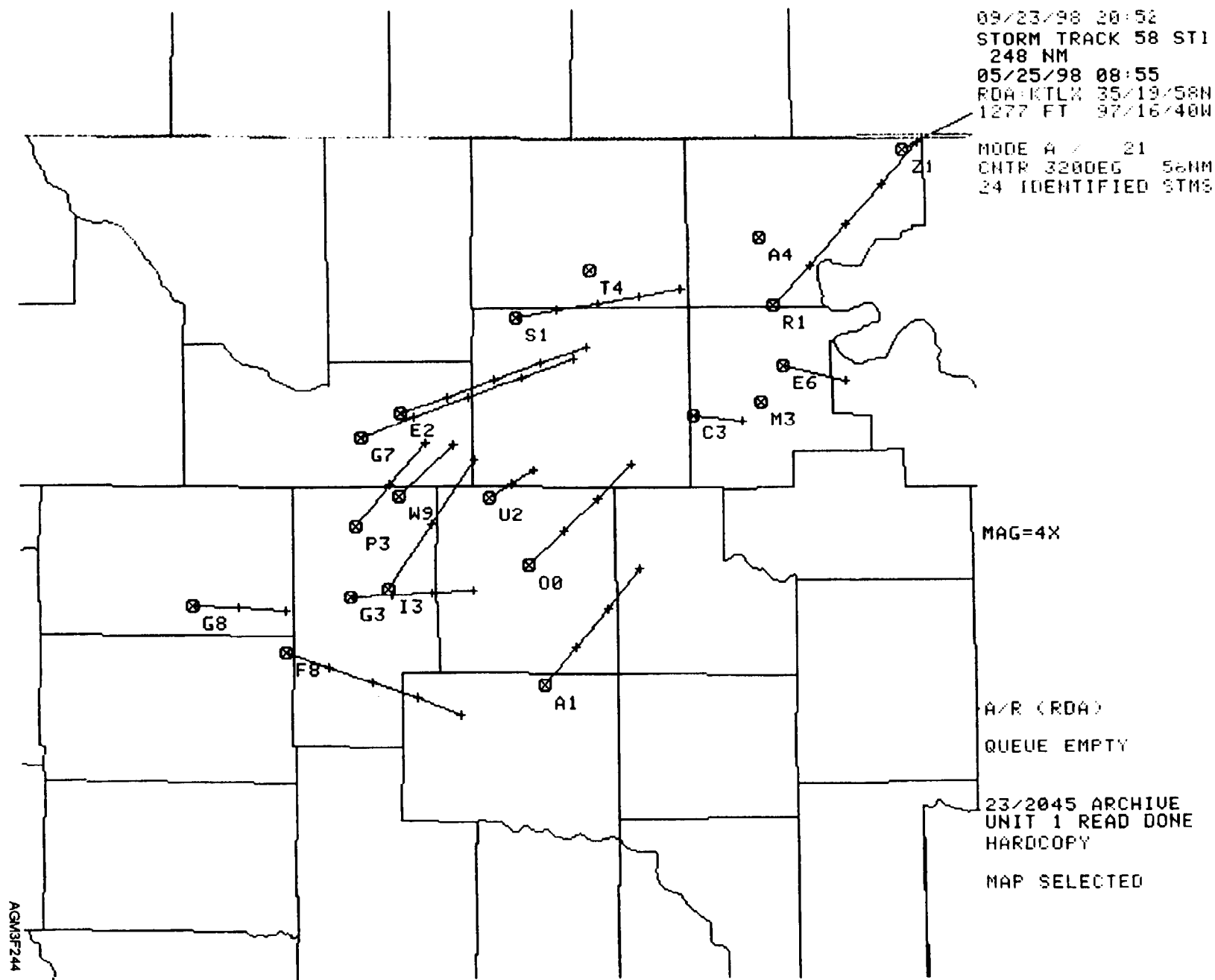
Figure 2-44.—Storm Track Information (STI) product.

2-45, each storm is assigned a unique alphanumeric identifier. The small green triangles that are not filled in indicate the probability of hail of any size within that particular storm. The small green filled triangles indicate the probability of hail equal to or greater than 3/4 of an inch. The numbers inside the larger green triangles indicate maximum expected hail size to the nearest whole inch. In any case, the Hail Index product quickly indicates the possibility of severe weather in the radar coverage area.

Hail is a volumetric product, therefore, it is only available at the end of a volume scan. It requires input from several sources, and contamination at any level results in a loss of the product. While the hail product is nice to have, it should be routinely verified using VIL and VEL.

Reflectivity Cross-Section (RCS) Product

Cross sections provide a unique perspective of the atmosphere. They create an illusion that places you, the operator, into the heart of a target. This allows you to view meteorological targets, such as mesocyclones, from the inside. Cross-section products can be built from any of three radar moments (reflectivity, velocity, and spectrum width) and are primarily used to examine vertical storm structure. All cross-section products operate on essentially the same principle. That is, they allow a vertical depiction of the atmosphere by compiling base data vertically, along a user-defined direction. Data from a cross-section product is presented in a range (up to 124 nmi) versus height (up to 70,000 feet) format.

The Reflectivity Cross-Section (RCS) product is helpful even during nonconvective events. The depth of moist layers can be determined by the vertical extent (thickness) of scatterers. When cross sections are cut across frontal boundaries, frontal slope can be determined. For observing purposes, RCS is a good tool for measuring cloud bases and tops, and inversion boundaries. Clouds generally appear as well-defined layers, with a significant decrease in energy (dBZs) at the cloud's edge. Of course, RSC is very useful when evaluating severe weather potential. It permits three-dimensional analysis of storm dynamics and lets you determine the extensiveness or depth of a given feature. RCS is also an excellent product for locating WERs, BWERs, and maximum reflectivity cores. Figure 2-46 is an example of the RCS product.

The selection and placement of the cross section is extremely important. Even slight deviations often result in misanalysis of anticipated features (hooks, BWER, etc.). Also be aware that targets displayed by RCS are not always meteorological, but may be the result of birds, insects, etc.

Velocity Cross-Section (VCS) Product

When it comes to storm interrogation, no analysis is complete without a thorough look at velocity data. The Velocity Cross-Section (VCS) product provides a vertical cross section of velocity data. It is available in two different modes; clear-air and precipitation.

In clear-air mode (mode A), the Vertical Cross-Section (VCS) product can determine the existence and depth of turbulent layers and determine the intensity of wind shear. Boundaries and frontal slopes are evident by significant changes in wind speed or direction. These features are often more visible here rather than on an RCS product. In precipitation mode (mode B), the existence, strength, and vertical depth of vortices (areas of rotation) are analyzed. These may confirm the presence of mesocyclones or tornadoes and make a strong case for severe weather when linked to other products. VCS is an excellent tool for determining divergence, convergence, and cyclonic and anticyclonic rotation. Figure 2-47 is an example of the Velocity Cross-Section product.

The limitations of this product are similar to the Reflectivity Cross-Section product. Keep in mind that the plane along which the cross section is built MUST be either parallel or perpendicular to the radar viewing direction. If the cross section is cut at any other angle, you are viewing the radial component of radial velocities. This makes the data extremely hard to interpret.

RADAR CODED MESSAGES

The Radar Coded Message is a high-resolution product that provides summary radar information. It is primarily used in the preparation of the National Radar Summary Chart. The message is composed of three parts. Part A is a reflectivity graphic product that is automatically generated by the system. The local grid at each antenna site is designed to become part of the national radar grid. Part B contains a single profile of the horizontal wind information derived from the output of the Velocity Azimuth Display (VAD) algorithm. It is also produced automatically and is presented to the user as an alphanumeric message. Part C contains remarks in an alphanumeric format. Remarks, such as tornadic vortex signatures,
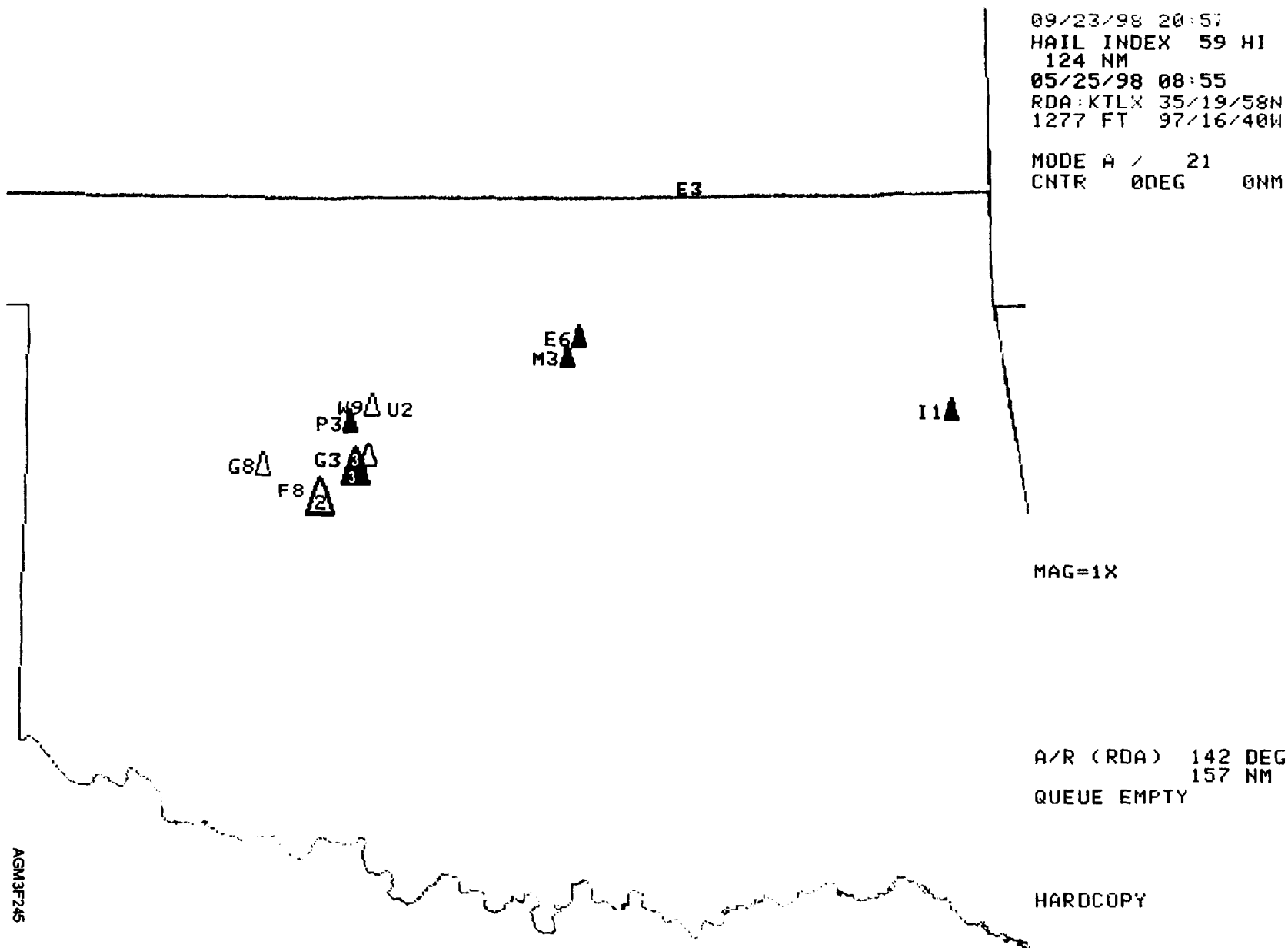
09/23/98 20:57
HAIL INDEX   59 HI
   124 NM
05/25/98 08:55
RDA:KTLX 35/19/58N
1277 FT 97/16/40W

MODE A /   21
CNTR   0DEG   0NM

E3

E6▲
M3▲

W9△ U2
P3▲

G8△   G3 △△
F8 △
   2

I1▲

MAG=1X

A/R (RDA) 142 DEG
           157 NM
QUEUE EMPTY

HARDCOPY

AGM3F245

Figure 2-45.—Hail Index (HI) product.
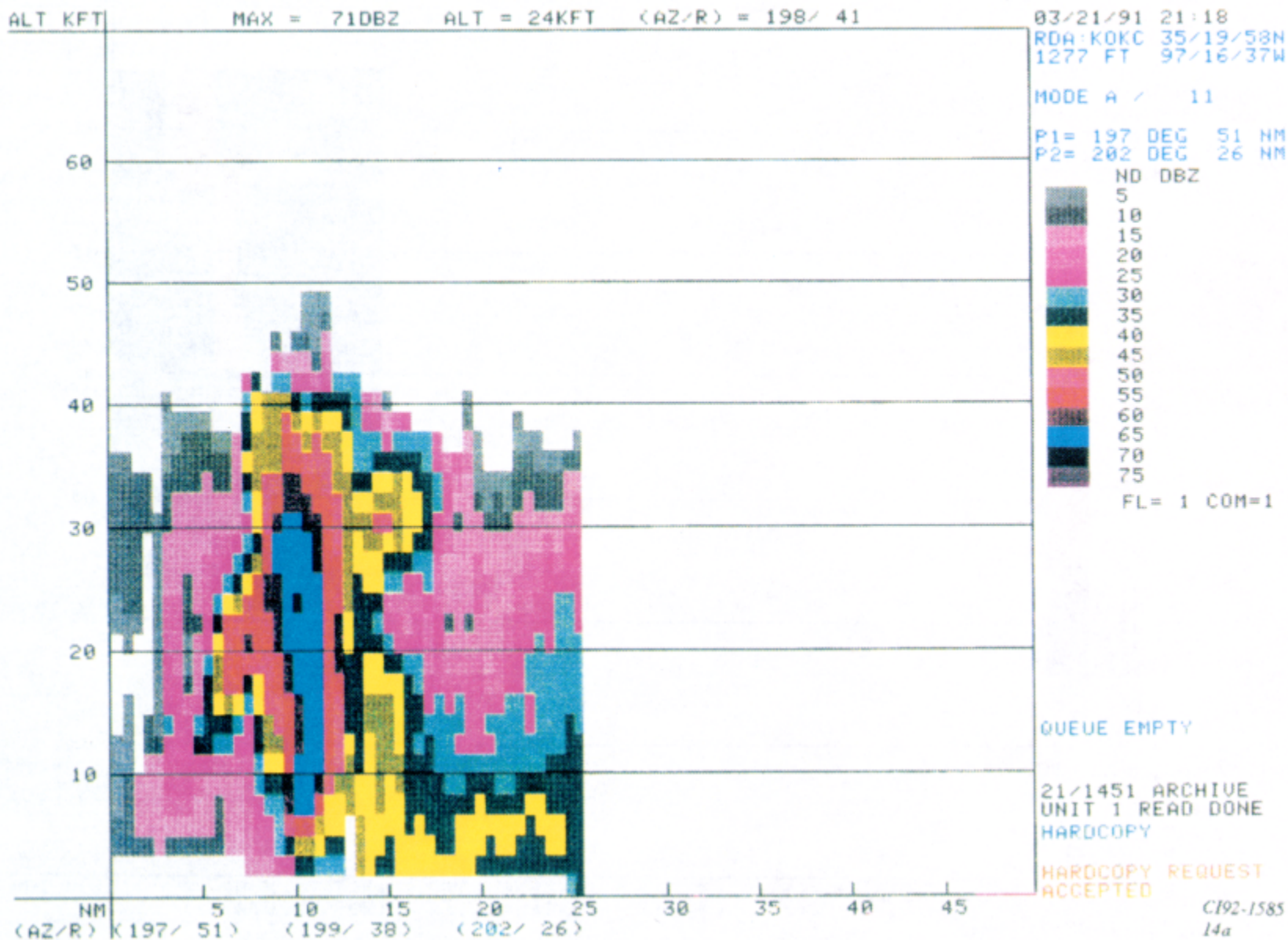
Figure 2-46.—Reflectivity Cross-Section (RCS) product.
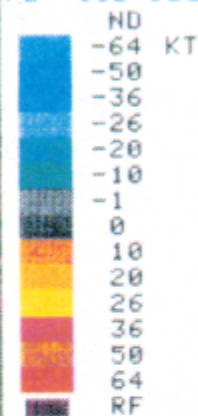
Figure 2-47.—Velocity Cross-Section (VCS) product.

mesocyclones, centroids, storm tops, and hail indices are all automatically generated. In addition to the automatically generated remarks, Part C provides for optional manual entries. Appendix III provides a listing of definitions and symbols that are routinely used in the remarks section.

REVIEW QUESTIONS

Q66. *What do the plotted heights on the Echo Tops (ET) product indicate?*

Q67. *What is displayed on the Severe Weather Probability (SWP) product?*

Q68. *What is a mesocyclone?*

Q69. *The Tornadic Vortex Signature (TVS) product is derived from what data?*

Q70. *How long will the Storm Track Indicator (STI) product track an individual storm?*

Q71. *What information does the Hail Index (HI) product provide?*

Q72. *What is the primary purpose of the Reflectivity Cross-section (RCS) product?*

Q73. *How could the Reflectivity Cross-Section (RCS) product be useful to an observer?*

Q74. *What information can be obtained from the Vertical Cross-Section (VCS) product in clear-air mode?*

Q75. *What does the symbol "ZR " indicate in a Radar Coded Message?*

WSR-88D PUBLICATIONS

LEARNING OBJECTIVE: Identify the publications associated with the WSR-88D system.

The Federal Meteorological Handbook No. 11 (FMH-11), *Doppler Radar Meteorological Observations,* is the governing manual for Doppler weather radar observations and consists of four parts. Part A, *System Concepts, Responsibilities. and Procedures,* explains the overall concept of the WSR-88D program and details site responsibilities and outlines general procedures. It also contains default values for the WSR-88D. Part B, *Doppler Radar Theory and Meteorology,* contains a detailed description of the WSR-88D along with a functional overview of system components. It also contains valuable information on the interpretation of Doppler velocity patterns. Part C, *WSR-88D Products and Algorithms,* describes the various products and algorithms of the WSR-88D, and provides information on the different operational modes. Part D, *WSR-88D Unit Description and Operational Applications,* provides an in-depth description of the various components of the WSR-88D and discusses the operational applications of meteorological and non-meteorological echoes.

The *Operator's Handbook, Principal User Processor,* consists of three volumes and is the best guide to learning the operation of the PUP workstation. Volume I contains information on the graphic tablet and Volume II contains information on the applications terminal. Volume III details information on the system console.

SUMMARY

In this chapter, we covered the WSR-88D Doppler weather radar system. We began with a discussion of electromagnetic energy and radar theory. Then we discussed the basic principles of radar propagation and the effects of atmospheric variables on this propagation. We then introduced you to Doppler radar theory and discussed the configuration and communications system of the WSR-88D. We completed the chapter with an overview of the strengths and limitations of the products available from the WSR-88D.

ANSWERS TO REVIEW QUESTIONS

A1.   An electromagnetic wave is radiation energy in the form of a sine wave with both electrical and magnetic properties.

A2.   Radio (microwave) region.

A3.   Centimeters or degrees.

A4.   Shorter wavelengths provide finer detail. Longer wavelengths are more effective when evaluating larger targets.

A5.   Frequency is the number of completed wave cycles per second, measured in hertz.

A6.   100 GHz.

A7.   By using the decibel system.

A8.   Reflectivity is the amount of energy returned from an object and is dependent on the size, shape, and composition of the object.

A9.   The antenna.

A10.   The sensitivity of a radar is the measure of the radar's internal interference against the minimum signal it is designed to detect.

A11.   Longer pulses return more power, thus increased target information and data reliability.

A12.   In seconads or kilometers.

A13.   Resolution refers to the ability of the radar to display multiple targets clearly and separately.

A14.   The rate at which pulses are transmitted per second.

A15.   An increase in PRF provides greater target detail; however, the maximum range of the radar is reduced.

A16.   The inability of the radar to distinguish between return pulses, producing ambiguous (unreliable) range information.

A17.   93 miles (81 nmi).

A18.   A pulse from a distance outside the radar's normal range returns during the next pulse's listening time, causing confusion.

A19.   As the pulse moves away from the radar, volume expands and power density decreases.

A20.   The smaller beam.

A21. Beam broadening increases pulse volume resulting in decreased signal strength.

A22. The presence of sidelobes leads to confusion in interpreting targets because short-range, non-meteorological targets are displayed along with main beam targets.

A23. An increase in beamwidth or target distance.

A24. Pulse length.

A25. The bending of (electromagnetic) waves.

A26. Moisture.

A27. N-units normally decrease with height.

A28. Subrefraction.

A29. A strong inversion,

A30. The existence of buildings, trees, or rough terrain near the radar antenna.

A31. Backscattering.

A32. Absorbers are mainly oxygen and water vapor.

A33. A means to measure motion.

A34. The outstanding capabilities of the WSR-88D include velocity detection, increased power and sensitivity, and the integration of high tech computers.

A35. It increases.

A36. A phase shaft is an observable repositioning of a point on a wave between successive transmissions.

A37. In degrees.

A38. By measuring phase shift, wavelength, and the time interval between pulses.

A39. As a target moves more perpendicular to a radar, the velocity detected becomes less than the true velocity.

A40. Velocity aliasing is a process that causes a Doppler radar to display untrue velocities because of the motion of the target.

A41. The Nyquist velocity is the maximum unambiguous velocity that can be detected at any given pulse repetition frequency (PRF).

A42. 29.4 mps (57 knots).

A43. Velocity aliasing and range folding.

A44. Radar Data Acquisition (RDA).

A45. Hail.

A46. Ground clutter and range folding.

A47. The Radar Product Generator (RPG).

A48. Base products are near real-time displays and are available after each scan. Derived products are base products that have been modified or enhanced to produce special results.

A49. Principal User Processor (PUP).

A50. A graphic tablet and puck

A51. Associated Principal Users (APUPs).

A52. Dedicated telephone lines.

A53. Archive Level IV

A54. A volumetric product requires the entire volume of radar coverage (all elevation angles) to be scanned.

A55. Mode A, VCP 11.

A56. Precipitation measurement, storm warnings, and wind profiling.

A57. The RPS provides an automated way of managing RPG workload and allows users to identify and access up to 20 routinely required products.

A58. Alert-paired products are transmitted whenever criteria for severe weather is met. They are sent in conjunction with an alert message.

A59. Reflectivity values from scatterers in the radars viewing area.

A60. Tornadoes.

A61. Velocities moving toward the radar (negative values).

A62. The RDA.

A63. Lack of target height information.

A64. To display an estimate of the atmosphere's liquid water vapor content in the vertical.

A65. Few scatterers in the atmosphere, thus drier air.

A66. Precipitation.

A67. *The Severe Weather Probability (SWP) product displays only strong convective cells and assigns percentage values based on each cell's chances of producing severe weather.*

A68. *A mesocyclone is an area of strong cyclonic rotation found in supercell thunderstorms.*

A69. *Base velocity*

A70. *One hour.*

A71. *The Hail Index product provides estimates on the probability of hail, the probability of severe hail, and the maximum expected hail size.*

A72. *To view meteorological targets in the vertical (from the side).*

A73. *The observer can determine cloud layer height and inversion layer height.*

A74. *Depth of turbulent layers, wind shear intensity, boundaries and frontal slopes.*

A75. *Freezing rain.*